Improving air filter efficiency as a strategy to reduce children's exposure to traffic-related air pollutants in energy-efficient classrooms

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SUMMARY
This study was organised to quantify the effect of upgrading the filter efficiency in balance ventilation systems on indoor exposure to traffic-related air pollution, in 4 primary school classrooms. The standard air filters (EU F7) were compared with more efficient EU F9, and with F7+active carbon filters. Particulate matter (PM), ultrafine particles (UFP), black carbon (BC), $PM_{2.5}$, organic/elemental carbon in $PM_{2.5}$ (EC/OC), and NO_2 were quantified, air tightness and air supply rates were assessed and pupils' indoor comfort was surveyed. Analysis of indoor air as function of outdoor air and filter type indicated a significant but small reduction of indoor levels when upgrading the filter, except for PM_{10}, TSP and UFP. The indoor comfort survey indicated a small but significant and positive effect as well.

PRACTICAL IMPLICATIONS
Upgrading the typically used fine dust filter in Belgian school balance ventilation systems (EU F7) to a more efficient one (EU F9), did not lead to a considerable exposure reduction of pupils. However, the habit of using fine dust filters (F-type) without a coarse dust filter in sequence, reduces the filter lifetime and increases clogging of the filter.

KEYWORDS
Air filter, balance ventilation, exposure reduction, black carbon, indoor comfort

1 INTRODUCTION
A lack of school buildings and space in larger cities of Northern Belgium forces the construction of new schools in highly urbanised areas. Children's health is a governmental priority and policy aims at providing guidelines for reducing children's exposures at school; guidelines on ventilation design are part of these actions (Chan et al. 2015).

2 MATERIALS/METHODS
In 4 classrooms of different primary schools with nearby traffic (< 50m from major road), an 8-week air sampling campaign was organized between June 2014 and March 2015. The standard air filters (EU F7) weekly alternated with more efficient EU F9 filters and during one week an F7+active carbon (AC) filter was installed. Indoor and outdoor continuous monitoring of PM and UFP (Grimm Nanocheck), BC (micro aethalometer), $PM_{2.5}$ (MS&T Harvard type impactor), organic and elemental carbon (MS&T Harvard type impactor, Quartz fibre), and NO_2 (Gradko Rapid Air Monitor) was organised. Air tightness and air supply rates were assessed in each classroom and pupils participated in an indoor comfort survey

(Momentary questionnaire). Indoor air concentrations ($conc_{indoor}$) were studied as a function of their outdoor levels ($conc_{outdoor}$) as well as the air filter in the ventilation system (filter), using a multiple linear regression model. The predicted indoor concentrations were expressed as (1).

$$conc_{indoor} = b_1 + b_2 * conc_{outdoor} + b_3 * filter \qquad (1)$$

'filter' being a categorical predictor (value 1 for F9 filters, and value 0 for F7 filters). Later a concentration dependence of the filter efficiency (interaction) was added to the model.

3 RESULTS

Upgrading the filter efficiency was found to have only a small impact on the flow rate, but a clogged filter was found to significantly decrease the air flow rate. The indoor comfort in the classrooms, described by means of perceived health complaints and perceived quality of the environment scales, indicated a small but significant effect of upgrading an F7 filter to an F7+AC or F9 filter on perceived health complaints, and of upgrading an F7 filter to an F7+AC filter on perceived quality of the environment. Active carbon F7 filtration was indicated to reduce indoor volatile organic compounds (VOCs) (I/O TVOC with F7 or F9 was 1.43, reduced to 0.93 with F7+AC filtration), indoor NO_2 was less affected.

Multiple linear regression analysis led to significant and negative regression coefficients of the categorical predictor: upgrading filters leads to decreased indoor levels. Predicted indoor levels for F9 vs. F7 compared to outdoors for UFP (-79% vs. -69%), BC (-65% vs. -49%) and various PM fractions (e.g. $PM_{2.5}$ -87% vs. -82%) differed significantly. For larger PM fractions, the R^2-value of the model and the difference between F7 and F9 both decreased. Introducing an interaction between outdoor air and filter efficiency in the model, R^2 increased moderately compared to the more simple model and interactions were represented by significant regression coefficients ($p<0.05$).

4 DISCUSSION

Assuming no interaction in the model, R^2 values indicate that the model explains most of the indoor air data variability when considering particles < 0.3µm (R^2 = 0.42 – 0.67), PM_1 (0.3 – 0.68) and BC (0.48 – 0.62). R^2 values are lower for $PM_{2.5}$, PM_{10} and UFP. A hypothetical outdoor PM_1 concentration of 20 µg/m³ would e.g. lead to indoor levels of 3.92 µg/m³ with F7 air filtration and 2.35 µg/m³ with F9. Therefore it should be noted that even though differences between F7 and F9 are statistically significant, a demonstration using representative ambient air levels, leads to predicted indoor air concentrations differing only little (less than 1 µg/m³). When assuming interaction in the model, predicted indoor levels using F7 tend to become significantly lower compared to F9 at very high outdoor levels ($PM_{2.5}$>200 µg/m³), possibly related to clogging of the most efficient filter.

5 CONCLUSIONS

Even though predicted indoor levels for F7 and F9 were found to be significantly different, a demonstration using representative ambient air levels led indoor concentrations differing 1 µg/m³ or less between the two conditions. This study indicated that IAQ benefits of upgrading the air filters from F7 to F9 could be less significant from a health based perspective.

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6 REFERENCES

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